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POTENTIAL USE OF LOW-YIELD NUCLEAR WEAPONS IN A KOREAN CONTEXT

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Abstract

This report explores the potential uses of low-yield nuclear weapons in the context of a possible conflict on the Korean Peninsula. It starts with a definition of low-yield weapons—typically, weapons with yields of ten kilotons or less that are designed to be nonstrategic or “tactical” weapons used with shorter-range delivery systems, prepared for the purpose of attacking troops or battlefield infrastructure. The paper then reviews the history of United States legislation regarding low-yield weapons and describes three generic scenarios in which foes possessing low-yield weapons might choose, or not choose, to use them during a military conflict. Examples of radioactive fallout maps are provided based on HYSPLIT modeling for explosions of 0, 3 and 10 kilotons at a location in the Korean demilitarized zone at different times of the year. The arsenals of low-yield weapons in the states possessing nuclear weapons in Northeast Asia, as well as the United States, are compared, and seven possible “use cases” for low-yield nuclear weapons involving the Korean Peninsula are put forward.

Note on Sources and Content

This report has been prepared based on a survey of the current literature and opinions on these topics to initially advise the development of plausible nuclear use cases for a three-year modeling project spearheaded by RECNA, PSNA, Nautilus Institute, and APLN. One-on-one interviews were conducted with topical experts Mike Hynes,¹ Jungmin Kang,² Feroz Khan,³ Henry Sokolski,⁴ and Frank von Hippel,⁵ although the contents of this report do not necessarily reflect their views. This report suggests possible cases in which low-yield nuclear weapons may be used, generally and specifically regarding the conflict on the Korean Peninsula. It does not thoroughly address the plausibility of such cases, and a more in-depth treatment of this topic is required to fully understand the breadth and complexity of nuclear deterrence theory involving low-yield nuclear weapons.

¹Bele, Jean, Michael Hynes, and Robert Redwine. MIT Nuclear Weapons Education Project. Last modified 2021.

²Jungmin Kang." Biography found at Bulletin of the Atomic Scientists. Last modified 2021.

³Feroz Khan, BG (Retired)." Naval Postgraduate School. Last modified August 2021.

⁴Henry D. Sokolski, Executive Director." Nonproliferation Policy Education Center. Accessed September 2021.

⁵Frank von Hippel." Princeton University: Program on Science & Global Security. Accessed September 2021.

Introduction

The first nuclear weapon had a yield of approximately 20 kilotons,”⁶ or kt, based on Manhattan Project tests and weapons detonated in World War II. Although nuclear weapon states now have the capability to detonate weapons with yields thousands of times greater than this (megaton-scale weapons), the resulting devastation at Hiroshima and Nagasaki showed that the destruction and death caused by relatively small weapons is appalling enough. For this reason, nuclear weapon states developed and continue to maintain “low-yield” nuclear weapons or nuclear weapons with adjustable yields, including low-yield options in their arsenals—weapons originally designed to be used in “tactical” missions that attempt to avoid the staggeringly high civilian death tolls seen in World War II. Two of the Non-proliferation of Nuclear Weapons Treaty-compliant nuclear-armed states party to the conflict on the Korean Peninsula—the United States and Russia—possess low-yield nuclear weapons. The publicly-reported and observed nuclear arsenals of China and the Democratic People’s Republic of Korea (DPRK) do not include low-yield nuclear weapons, but both states possess weapon technology that could be reduced to yields of 10 kt or less. If a nuclear-armed state were to detonate a low-yield nuclear weapon, it might be to minimize or avoid civilian casualties, to achieve “limited” or “tactical” military objectives, to try to avoid an all-out nuclear war, to limit damage to its international reputation, or as a demonstration or warning strike.

During the Cold War, nuclear weapon states deployed low-yield nuclear weapons (LYNWs – 10 kt or less) to be used primarily in tactical or nonstrategic missions, such as deterring the advance of conventional military forces on the battlefield. As conventional weapon systems evolve to be able to home in on their targets, LYNWs may become somewhat obsolete or unneeded to offset enemy conventional forces. Modern-day scenarios resulting in escalation to the use of LYNWs on the Korean Peninsula may be replaced by the use of highly-advanced drones or precision-guided munitions. For nations lacking an advanced military, however, the use of LYNWs may still be perceived as advantageous on the battlefield. Simulations of LYNWs suggest that the intentional use of LYNWs in a traditional Cold War-era manner is unlikely because the radioactive fallout may have a negative impact on the user’s own territory or forces. Some scenarios can be envisioned, however, in which a state may attempt to use a fallout cloud to its own advantage.

More likely is that a LYNW might be detonated as a demonstration or warning strike, to incapacitate naval forces, or through accident. To develop plausible scenarios involving these suggestions, it is important to reason why the state would choose a low-yield nuclear weapon over a conventional weapon.

⁶*Dictionary of Military and Associated Terms*. S.v. “nominal weapon.” Retrieved August 12, 2021, from <https://www.thefreedictionary.com/nominal+weapon>

Definition of a Low-Yield Nuclear Weapon

Although there has been some debate over what constitutes a “low-yield” nuclear weapon, one definition of “low-yield” is ten kilotons or less.⁷ Furthermore, some ambiguity exists with regard to the exact definition of a “kiloton” (see Appendix A), with different states, and sometimes even organizations within states, often defining the term “kt weapon” somewhat differently.

During the Cold War, the United States and USSR developed and deployed strategic and nonstrategic nuclear weapons. Most analysts consider nonstrategic weapons to be shorter-range delivery systems with lower-yield warheads prepared for the purpose of attacking troops or battlefield infrastructure.⁸ They are also prepared for the purpose of homeland defense, particularly in the Russian case.⁹ However, “low-yield” and “nonstrategic” are not synonymous. Kristensen and Korda, writing in *The Bulletin of the Atomic Scientists*,¹⁰ explain:

A frequent and widespread mistake in the public debate is to equate nonstrategic with low yield. If a weapon has a low-yield option, so the thinking goes, then it’s a nonstrategic weapon; conversely, if it has a high yield, then it must be a strategic weapon. The reality is much more blurred and complex; some nonstrategic nuclear weapons have high-yield options, some strategic weapons have low-yield options; some have both. (Kristensen & Korda, 2019, p. 254)

Therefore, it can be said that low-yield nuclear weapons are most often considered when planning nonstrategic (or “tactical”) and defensive nuclear use policies, but they are also considered in strategic nuclear deterrence theory.

The nuclear weapon arsenals of the United States and Russia include low-yield warheads prepared for use with both strategic and nonstrategic delivery systems. Strategic delivery systems carrying low-yield warheads are submarine-launched ballistic missiles (SLBMs), and bomber aircraft, which carry dial-a-yield warheads. Nonstrategic delivery systems are fighter aircraft, antiballistic missiles for coastal defense, air defenses, ground-based mobile short-range ballistic missile systems,¹¹ and possibly bomber aircraft.

⁷Woolf, Amy F. "A Low-Yield, Submarine-Launched Nuclear Warhead: Overview of the Expert Debate." Last modified January 5, 2021. Congressional Research Service (IF11143).

⁸Woolf, Amy F. "Nonstrategic Nuclear Weapons." Last modified July 15, 2021. Congressional Research Service (RL32572).

⁹Hans M. Kristensen & Matt Korda (2021), Russian nuclear weapons, 2021, *Bulletin of the Atomic Scientists*, 77:2, 90-108, DOI: 10.1080/00963402.2021.1885869.

¹⁰Hans M. Kristensen & Matt Korda (2019), Tactical nuclear weapons, 2019, *Bulletin of the Atomic Scientists*, 75:5, 252-261, DOI: 10.1080/00963402.2019.1654273.

¹¹ US and Russian ground-based short-range nuclear weapons were retired in 1991 by unilateral initiatives by US President George H.W. Bush and Soviet President Mikhail Gorbachev, although other countries still maintain such systems. See Arms Control Association (2017), “The Presidential Nuclear Initiatives (PNIs) on Tactical Nuclear Weapons at a Glance,” July, 2017, <https://www.armscontrol.org/factsheets/pniglance>

U.S. Legislation Involving Low-Yield Nuclear Weapons

During the Cold War, although longer-range “strategic” nuclear weapons became the primary focus of arms control negotiations, nonstrategic nuclear weapons “had a lower profile in policy debates ... possibly because they did not pose a direct threat to the continental United States.”¹² Some believe that the continued use and development of tactical nuclear weapons undermines existing arms control agreements, and could trigger further arms races that increase the risk of nuclear war.¹³

Domestically, the United States Congress has debated legislation to limit the research and development of low-yield nuclear weapons. Some argue that prohibiting the low-yield option limits the United States’ ability to deter or respond to emerging threats, particularly regional threats such as on the Korean Peninsula. Others argue that the development of very low-yield warheads can lower the nuclear-use threshold by softening the “nuclear taboo.”

In 1993, the House Armed Services Committee argued that “very low yield nuclear warheads threaten to blur the distinction between conventional and nuclear conflict, and could thus increase the chances of nuclear weapons use by another nation.” As a result, an amendment to the FY1994 National Defense Authorization Act known as the Precision Low-Yield Weapon Design ban (PLYWD) was passed that banned research on and development of low-yield nuclear weapons. This amendment defined “low-yield” as less than 5 kt. In 2001, following the publication of reports arguing that low-yield nuclear weapons could aid in the destruction of underground facilities, the Bush Administration called for the repeal of PLYWD. In 2004, the amendment was modified to allow research on, but restrict engineering development of, low-yield nuclear weapons unless specifically allowed by Congress.¹⁴

Low-Yield Nuclear Weapons as Nonstrategic or “Tactical” Weapons

Some low-yield nuclear warheads have been developed to be delivered as “nonstrategic” or “tactical” weapons. The original purpose of these weapons was to stop the advance of military forces or incapacitate a military base as opposed to threatening an attack on a city, infrastructure supporting the enemy’s war-making capacity, or civilian population. Even though improvements in delivery systems and conventional military technology have blurred the distinction between strategic and “tactical” weapons, the term “nonstrategic” still is used to describe nuclear weapons that would be detonated at shorter ranges and with lower yields to support a military commander’s mission with a limited scope. In theory, deployment is limited to the area of military operations.¹⁵ However, it has been hotly debated whether the use of nonstrategic weapons can actually remain limited to local battlefield consequences.

¹²Woolf, “Nonstrategic Nuclear Weapons,” Summary.

¹³Kristensen and Korda, “Tactical Nuclear Weapons, 2019,” p. 252.

¹⁴Woolf, Amy F. “New Nuclear Warheads: Legislative Provisions.” Last modified February 5, 2018. Congressional Research Service (IN10854).

¹⁵Woolf, “Nonstrategic Nuclear Weapons,” p. 8.

The three scenarios summarized below introduce nonstrategic low-yield nuclear deterrence theory. Any of these general scenarios could be used to envision a situation that may result in nuclear first-use. If both states involved possess nuclear weapons, scenarios with follow-on nuclear retaliation could then be analyzed.

Scenario 1: Cautious adversary deterred by low-yield nuclear deployment. Nation B invades Nation A and both of them either have nuclear weapons or are covered by a “nuclear umbrella” provided by a nuclear weapons state. Nation A announces that it has nonstrategic nuclear weapons deployed in the battlefield and may detonate them to stop the advance of Nation B. Because Nation B believes it is very unlikely for Nation A to follow through on the threat, Nation B continues its advance, testing Nation A’s nuclear use threshold. Fearing that deterrence has failed, Nation A becomes more committed to using its nuclear weapons on invading forces. As tensions rise, uncertainty and confusion grow in the mind of Nation B’s commander, whose invading army becomes so cautious in its advance that the operation becomes stalemated. Therefore, the purpose of Nation A’s tactical nuclear weapon has been fulfilled successfully, although the situation came to the brink of nuclear use before deescalating. *Low-yield nuclear weapons may be deployed but not detonated in a battlefield scenario in order to put the burden of risk calculation on the leaders of the invading army.*

Scenario 2: Low-yield deployment fails to deter a bold adversary, resulting in nuclear use by the defending nation. As in Scenario 1, Nation A has deployed nuclear weapons in the battlefield to cause confusion and hesitation in Nation B’s invading forces. Given that they are deployed in or near Nation A’s own territory or forces, Nation B is obliged to calculate whether Nation A will actually detonate the nuclear weapons. A bold Nation B decides to call Nation A’s bluff and test its resolve by continuing the advance. Nation B advances so far that Nation A fears that further advance will result in the capture of its entire country or a key military base or city. Since Nation A’s policy declares the use of nuclear weapons as a last resort, Nation A decides to detonate a low-yield nuclear weapon on Nation B’s invading forces. They begin by using a low-yield, nonstrategic nuclear weapon to minimize damage to their own country. If nuclear use is part of Nation B’s nuclear retaliation policy, Nation B may detonate one or more nuclear weapons of various yields in a last resort effort to finish its campaign, or it may back down after nuclear first-use by Nation A. If nuclear escalation continues, either side may end up threatening an enemy city with a higher-yield strategic nuclear weapon. *In this case, the low-yield nuclear option was used to preserve international reputation and manageable damage because it was used in defense on the nation’s own territory, which may lead to de-escalation of the conflict or nuclear retaliation and escalation.*

Scenario 3: Either nation skips the low-yield tactical option and threatens a strategic attack on an enemy city or other large target in an attempt to avoid nuclear use altogether.

Defending Nation A knows that if it were to be pushed to the last resort and detonate a low-yield nuclear weapon, it would still have broken the global “nuclear taboo.” Regardless of yield or size, in the end it is still a nuclear weapon. Because Nation A would greatly prefer to avoid the use of nuclear weapons entirely, it may instead try to rely on strategic deterrence, such as threatening an entire enemy city with an ICBM. Some believe that such countervalue threats provide better deterrence to successfully halt a military advance because the consequences of

such an attack are so high that it isn't worth the risk for invading Nation B, even if actual nuclear detonation is unlikely. *Threat of imminent strategic attack can be a preferable strategy if it enables the country to both stall enemy military operations and avoid nuclear use.*

These scenarios only begin to introduce the complex strands of deterrence theory that have motivated the deployment of low-yield, nonstrategic nuclear weapons, although relying on them for military deterrence is not attractive. Similar scenarios could develop in which each nation has different motives, such as deterring against the deployment of modern conventional weapons, invasion by naval troops massing along the coast, or the (re-)deployment of nuclear weapons by a nuclear weapons state to provide a nuclear umbrella to a non-nuclear state in a regional conflict, to suggest a few. Escalation scenarios might include factors such as nuclear use policies regarding retaliation, or factor in how mutually assured destruction can play into strategic nuclear deterrence, which would complicate Scenario 3 by making it more difficult for nations to make credible countervalue threats.

Some believe it is very unlikely for a nation to detonate a nonstrategic nuclear weapon, even a low-yield weapon, for three reasons, highlighted below:

1. If a low-yield nuclear weapon were detonated in the battlefield, the risk to the nation's own troops and nearby borders might be too great, depending on height of burst and other factors.
2. Low-yield nuclear weapons decrease the nuclear use threshold. The nation guilty of nuclear first-use would break the global "nuclear taboo," harming its international reputation. Instead, it could be preferable to threaten a higher-yield countervalue strike (such as against a major city) to achieve deterrence. Because the threat is more severe, in theory, strategic nuclear weapons provide better deterrence, decreasing the likelihood that a nuclear weapon of any kind will actually be used.
3. Advances in conventional military technology have increased the effectiveness and availability of precision-guided munitions and drones, arguably decreasing the need for low-yield nuclear weapons, depending on the specific circumstances of battle and the decisions of acting military commanders.

To approximate the possible radioactive fallout that could result from the detonation of a low-yield nuclear weapon, simulations of nuclear detonations were performed using the NOAA-ARL HYSPLIT software.¹⁶ The parameters used for these simulations are listed in Appendix B. Low-yield Uranium-235 fission devices of 10 kt and 0.3 kt were simulated as both airbursts and surface-bursts above ground at the third tunnel¹⁷ along the 38th Parallel, which is 27 miles from

¹⁶Stein, A.F., Draxler, R.R., Rolph, G.D., Stunder, B.J.B., Cohen, M.D., and Ngan, F., (2015). "NOAA's HYSPLIT atmospheric transport and dispersion modeling system," *Bull. Amer. Meteor. Soc.*, 96, 2059-2077, <http://dx.doi.org/10.1175/BAMS-D-14-00110.1>

¹⁷Two North Korean tunnels beneath the Korean Demilitarized Zone were discovered in 1974-75. An incomplete third tunnel was discovered 27 miles (44 km) from Seoul in 1978, possibly designed for a surprise attack on Seoul by North Korea. This tunnel has been described as a "tunnel of aggression" by South Korea. [J. F. Vesecky, W. A.

Seoul. The fallout due to a nuclear weapon detonated near the ground depends significantly on the prevailing wind speed and direction, as illustrated in Figure 1, which compares the fallout patterns due to a 10-kt surface-burst modeled on weather conditions prevailing on August 1 and January 1, 2021.

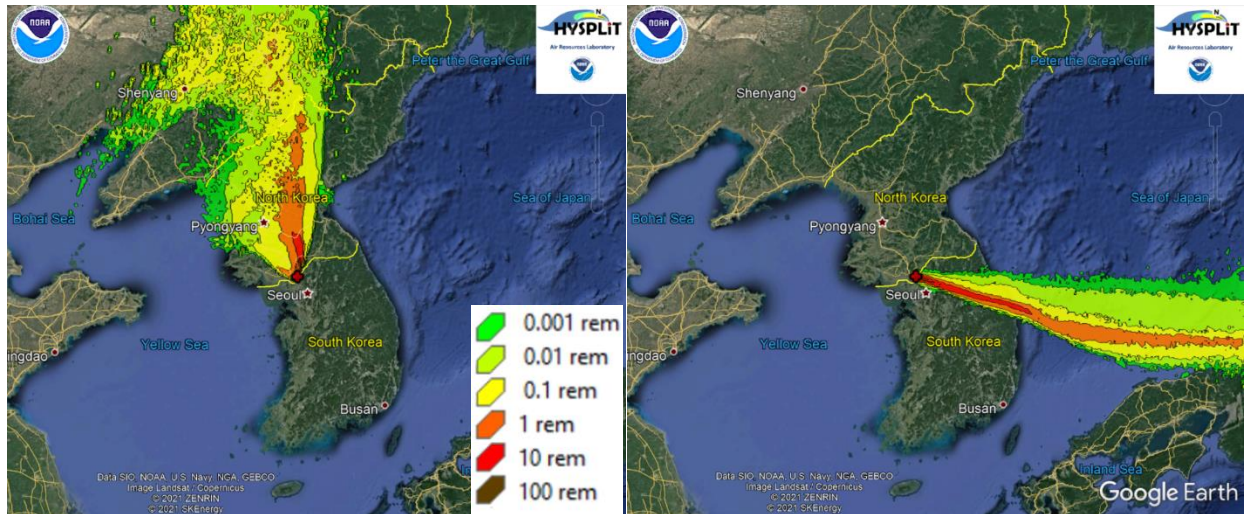


Figure 1: Nuclear fallout patterns four days after detonation from 10-kt surface-bursts modeled for weather conditions prevailing on August 1, 2021 (left) and January 1, 2021 (right). Doses below 100 rem would be expected not to have short-term effects.

Figure 2 illustrates hypothetical fallout extents as a result of 10-kt and 0.3-kt nuclear weapon detonations on August 1, 2021—surface-bursts and airbursts.

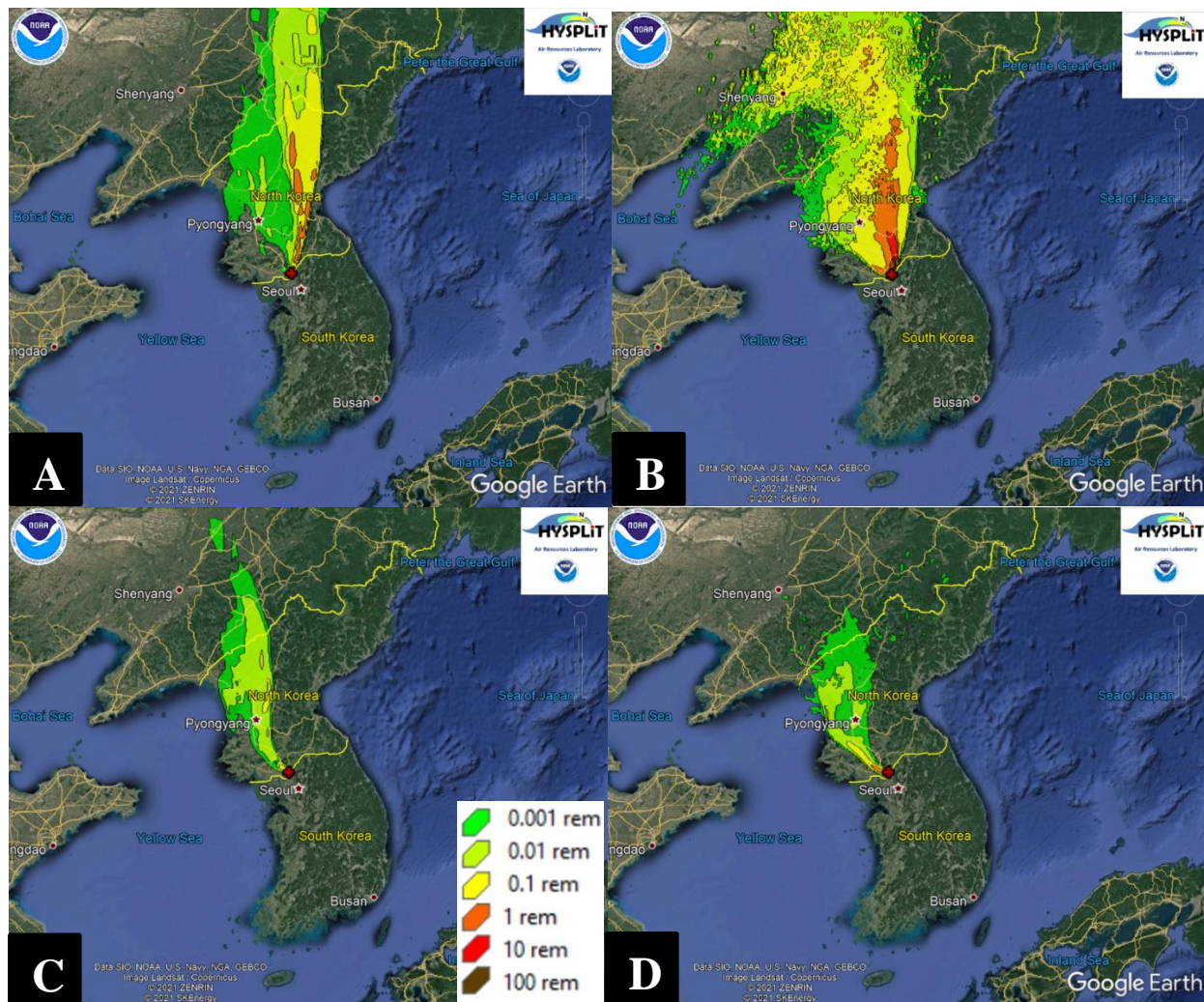


Figure 2: Nuclear fallout from low-yield detonations measured in accumulated radiation dose (rem¹⁸) after four days: (A) 10-kt airburst, (B) 10-kt surface-burst, (C) 0.3-kt airburst, (D) 0.3-kt surface-burst.

¹⁸The radiation levels indicated in the figures above are in units of rem or “Roentgen equivalent man,” a measure of the health effects of doses ionizing radiation on the human body. By way of comparison, the United States Nuclear Regulatory Commission provides the following guidance on how radiation doses correspond to different exposure guidelines and radiation health effects:

- 0.1 rem: Annual Dose Limit for Individual Members of the Public due to USNRC-licensed nuclear facilities
- 5 rem: Annual Dose Limit for Radiation Workers (USNRC)
- 10 rem: Definitive increased risk of cancer in lifetime.
- 50 rem: Considered a large radiation dose by the USNRC.
- 100 rem: Mild radiation sickness, Nausea, reddening of skin

Source: "Radiation and Its Health Effects." United States Nuclear Regulatory Commission. Last modified March 20, 2020. <https://www.nrc.gov/about-nrc/radiation/rad-health-effects.html>

This arbitrary scenario is for illustrative purposes only and is not posed here as a plausible nuclear weapons use case. These first-pass approximate simulations illustrate the potentially far-reaching consequences even low-yield nuclear use can have in a regional conflict. Low-yield nuclear attacks may have greater localized fallout because the optimum height of burst of low-yield weapons to maximize overpressure effects is closer to the ground; surface or near-surface-level weapons result in greater fallout.

Current Low-Yield Nuclear Weapon Arsenals

United States

As of November 2020, the US Department of Defense maintained an approximate total stockpile (all yields included) of 3,700 nuclear warheads, 1,750 of which are deployed. Land-based intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) account for approximately 400 and 1,000 warheads, respectively. There are about 300 warheads at bomber bases within the United States and 100 nonstrategic weapons stationed at bases in Europe.¹⁹ The remaining nonstrategic nuclear weapons are in storage within the United States. Table 1 summarizes the US low-yield nuclear weapon stockpile, a subset of an estimate made by Kristensen and Korda in the *Bulletin of the Atomic Scientists* in January 2021.²⁰

Table 1: U.S. low-yield Nuclear Forces, 2021

Type / Designation	Year deployed	Warheads x yield (kilotons)	Warheads (total)
SLBMs (Strategic) UGM-133A Trident II D5/LE Mk-4A	2019	1-2 W76-2 x 8 (MIRV)	25
Bombers (Strategic) B-52H Stratofortress B-2A Spirit	1961 1994	ALCM/W80-1 x 5-150 B61-7 x 10-360 B83-1 x low-1,200	528 322
Nonstrategic forces F-15E, F-16 DCA	1979	1-5 B61-3/-4 bombs x 0.3-170	230

Out of all low-yield weapons in the US nuclear arsenal, none are designed to be mounted on ICBMs, and only approximately twenty-five out of nearly 2,000 SLBMs warheads are low-yield. Bombers and fighter aircraft carry dial-a-yield warheads capable of yields within the ranges shown in the table.

The United States Trump Administration's 2018 Nuclear Posture Review (NPR) recommended the development of low-yield nuclear weapons to aid in deterrence against regional aggression. The 2018 NPR specifically calls for the modification of a small number of existing W76-1 90-kiloton two-stage thermonuclear warheads to single-stage warheads to limit the yield to around 8

¹⁹Hans M. Kristensen & Matt Korda (2021), "United States nuclear weapons, 2021," *Bulletin of the Atomic Scientists*, 77:1, 43-63, DOI: 10.1080/00963402.2020.1859865.

²⁰Ibid., p. 44.

kilotons. These low-yield weapons were intended to replace high-yield versions of these weapons so that the number of deployed warheads does not increase.²¹ Since the Biden Administration has yet to publish its own NPR, it remains to be seen if and how the development and modernization of the US low-yield nuclear stockpile may change course in the near future.

Russia

The nuclear arsenals of the United States and the Russian Federation are roughly equivalent as a result of bilateral arms control agreements between the two nations. As of 2021, Russia is estimated to have approximately 1,600 deployed strategic warheads on ballistic missiles and at bomber bases. Russia's approximately 1,900 nonstrategic warheads are all held in reserve. The nation is currently working to modernize its nuclear arsenal to replace many Soviet-era weapons.²²

Table 2 presents a subset of Kristensen and Korda's summary of current Russian nuclear forces, focusing only on Russia's stockpile of low-yield nuclear weapons.²³

Table 2: Russian low-yield nuclear forces, 2021

Type / name	Year deployed	Warheads x yield (kilotons)	Warheads (total)
<i>Nonstrategic and defensive weapons</i>			
ABM/Air/Coastal defense			
S-300/S-400 (SA-20/SA-21)	1992/2007	1 x low	~290
53T6 Gazelle	1986	1 x 10	68
SSC-5 Stooge (SS-N-26)	2015	1 x 10	25
Land-based air			
Bombers/fighters (Tu-22M3 (M3M) / Su-24M / Su-34 / MiG-31K)	1974-2018	ASMs, ALBM, bombs	~500
Ground-based			
SS-26 Stone SSM	2005	1 x 10-100	70
SSC-7 Southpaw GLCM			
SSC-8 Screwdriver GLCM	2017	1 x 10-100	20

China

As of November 2021, it is estimated that China possesses the world's third-largest nuclear arsenal, with a stockpile that includes around 350 operational warheads. China is currently working to further expand and, like Russia, modernize its nuclear arsenal.²⁴

²¹Ibid., p. 45.

²²Hans M. Kristensen & Matt Korda (2021), "Russian nuclear weapons, 2021," *Bulletin of the Atomic Scientists*, 77:2, 90-108, DOI: 10.1080/00963402.2021.1885869.

²³Ibid., p. 91.

²⁴Hans M. Kristensen & Matt Korda (2020), "Chinese nuclear forces, 2020," *Bulletin of the Atomic Scientists*, 76:6, 443-457, DOI: 10.1080/00963402.2020.1846432.

China possesses several megaton-scale warheads estimated to be 3.3 Mt and 4-5 Mt, but most of its known warheads are estimated to be in the 200-300 kiloton range—almost all mounted on land-based short, medium, and intermediate-range ballistic missiles, and a small fraction on SLBMs. It has not been reported that China possesses any low-yield nuclear weapons in its arsenal, but in recent years, a renewed effort has been made to develop weapons carriable by aircraft that could be classified as non-strategic.²⁵

Democratic People's Republic of Korea (DPRK)

The size and characteristics of the DPRK's nuclear arsenal have been cautiously estimated by Kristensen and Korda. The DPRK is estimated to have enough fissile material to construct 40-50 nuclear warheads but might have assembled 10-20 warheads for delivery by medium-range ballistic missiles.²⁶

From 2006-2016, the DPRK conducted five low- to mid-yield underground nuclear tests, gradually increasing in yield from a suspected 0.7–2 kt fizzle in 2006 to two Trinity-like 7–25 kt tests in 2016. Finally, one additional, much-higher-yield test (estimated at 70–280 kt) was conducted in 2017.²⁷ Although its nuclear testing history demonstrates that the DPRK is capable of detonating low-yield nuclear weapons, it is not clear whether the DPRK is prioritizing research on and production of higher-yield thermonuclear weapons or lower-yield fission weapons. If the DPRK is prioritizing single-stage fission weapons with yields of 10–20 kt, it may have enough fissile material to build 40–50 of these weapons.²⁸

In any case, it has been observed that the DPRK is developing short, medium, long-range, and intercontinental ballistic missiles. According to Kristensen and Korda, “no credible public information demonstrates that North Korea has developed nuclear warheads for delivery systems other than ballistic missiles ... If North Korea had wanted ..., it could potentially have developed a gravity bomb for delivery by a medium-range bomber.”²⁹

Low-Yield Nuclear Weapon Use Cases

The following nuclear weapon use cases might be envisioned in light of the three general scenarios illustrated earlier in this report. In-depth analyses would be required to thoroughly evaluate the plausibility of each case.

1) DPRK Nuclear Response to Advancing Forces

One plausible DPRK nuclear first-use case might be triggered if the DPRK government felt overtly threatened by invading forces. Perceiving that the most effective or only way to halt an

²⁵Ibid., p. 453.

²⁶Hans M. Kristensen & Matt Korda (2021), “North Korean nuclear weapons, 2021,” *Bulletin of the Atomic Scientists*, 77:4, 222-236, DOI: 10.1080/00963402.2021.1940803.

²⁷Kenausis, Luisa. "Status of World Nuclear Forces: North Korea." MIT Nuclear Weapons Education Project. Accessed September 19, 2021. <https://nuclearweaponsedproj.mit.edu/Node/63>

²⁸Kristensen and Korda, “North Korean nuclear weapons, 2021,” p. 223-24.

²⁹Ibid., p. 232.

enemy's advance and preserve the existence of the state would be to detonate a nuclear weapon, the DPRK might target the battlefield directly, detonate a weapon over open land or sea as a demonstration of resolve, or even attack a countervalue target. As illustrated in Scenario 2, a low-yield option might be attractive here to minimize damage to their own country as much as possible, or in the hopes of preventing further nuclear escalation. There are certainly many reasons to favor a low-yield nuclear option over a high-yield one.

2) Redeployment of US nuclear weapons to the Korean Peninsula

The aforementioned United States 2018 Nuclear Posture Review (NPR) recommended the development of new low-yield options for the nuclear arsenal to enhance the “flexibility and range of its tailored deterrence options ... important for the preservation of credible deterrence against regional aggression.”³⁰ This implies that the United States would not rule out the use of low-yield nuclear weapons in response to threats on the Korean Peninsula. Though subsequent NPRs may adopt different doctrines, this precedent cannot be discounted. This NPR outlines a nuclear response policy in reaction to “attacks on the U.S. or allied civilian population or infrastructure, attacks on U.S. or allied nuclear forces, their command and control, or warning and attack assessment capabilities,”³¹ including significant non-nuclear attacks. Other threats that may lead to a nuclear response are the rapid growth or emergence of chemical, biological, cyber, and conventional aggression.³²

On the Republic of Korea (ROK) side, the issue has also been hotly debated, recently reignited in 2017 by the DPRK's latest nuclear test.³³ Critics of redeployment argue that deterrence using low-yield tactical nuclear weapons on the 38th-parallel is obsolete due to advancements made in precision-guided munitions and surveillance technology since the Cold War. The perceived obsolescence of tactical nuclear weapon technology by some military and political figures was one reason why tactical nuclear weapons were removed from the ROK in 1991.³⁴

3) Nuclear response to deployment of ships in the Sea of Japan

Use of a low-yield nuclear weapon on the sea may be appropriate if the attacking nation aims to avoid local fallout over nearby civilian populations. One hypothetical case: in an attempt to take out an aircraft carrier or naval fleet, the fallout may unexpectedly blow towards land, increasing the risk of nuclear escalation/retaliation. To imagine this case, why the attacking force would choose a nuclear option over a modern conventional option must be explained. (For example, the attacking force may not possess modernized or sufficient conventional forces.)

³⁰*Nuclear Posture Review: 2018*. Online: U.S. Department of Defense, 2018. Accessed September 25, 2021.

³¹*Ibid.*, p. 21.

³²*Ibid.*, p. 38.

³³German Radio. "South Korea to Bring Back US Tactical Nuclear Missiles?" *DefenceTalk.com*, September 8, 2017. <https://www.defencetalk.com/south-korea-to-bring-back-us-tactical-nuclear-missiles-70430/>

³⁴Keck, Zachary. "4 Reasons America Shouldn't Send Nuclear Weapons to South Korea or Japan." *The National Interest*, September 15, 2017. <https://nationalinterest.org/blog/the-buzz/4-reasons-america-shouldnt-sent-nuclear-weapons-south-korea-22339>

4) Incapacitate a military base or deny regional access

A state could try to incapacitate an enemy military base, deny access to a region, or create a buffer zone by attempting to use local nuclear fallout to prevent anyone from accessing that area. The author is not aware of any historical precedent or doctrine that would suggest this to be a likely scenario, but by examining Figure 1, it can be hypothesized that, by detonating a nuclear weapon of a specific yield at a carefully-selected height of burst, and keeping in mind prevailing or predicted wind patterns, in theory a desired fallout effect could be produced.

Such a preventative strike might be made with the goal of denying an enemy force access to a certain area, or passage through a certain area, due to radioactive contamination. There are, however, several factors that might make this case unlikely. Since most military bases are somewhat near a civilian population, it would be difficult to completely avoid collateral damage or collateral fallout, decreasing the attractiveness of this option. Second, it may be that most modern armies can now operate in low-fallout circumstances using protective gear and decontamination equipment, allowing the army to acquire access to the military base anyway. Given these various considerations, when developing hypothetical use cases, it must be thoroughly reasoned why nuclear weapon use would be necessary to incapacitate a military base or deny regional access in lieu of conventional weaponry.

5) Accidental detonation caused by invading forces

Even if it becomes counterproductive to use nuclear weapons to deny access to a military base as described in case #3, there might be another possibility that could result in the escalation of nuclear war – the accidental detonation of an enemy’s low-yield tactical nuclear weapons caused by military forces unknowingly attacking or invading a base where nuclear warheads are deployed for strategic or non-strategic deterrence. In this case, the invading nation may suspect that this was not in fact an accidental detonation, but rather an intentional use of low-yield nuclear weapons, and it may retaliate with its own low-yield nuclear use.

6) Low-yield nuclear demonstration alongside conventional combat

Because it has been said that the deployment of low-yield nuclear weapons lowers the threshold of nuclear use, demonstration strikes with low-yield nuclear weapons on land or sea might be attractive to a nation that wishes to avoid a direct nuclear attack but to also maintain credible deterrence in the face of rising military tensions and possible large-scale nuclear escalation.

7) Low-yield nuclear use is met with a more powerful conventional attack

Due to the aforementioned technological advancements made in modern weaponry, it may be that if a state with relatively primitive nuclear weapon technology detonates a low or mid-yield nuclear weapon on military forces with very advanced conventional capabilities such as the United States, nuclear war may remain limited to preserve the international reputation of the United States. This has perhaps been made possible by the development of conventional technology that is so advanced that the United States does not feel the need to respond to a nuclear attack with another nuclear attack. In this way, the technological advancement of conventional weaponry could cause a nuclear conflict to remain “limited” following the detonation of a nuclear weapon.

8) Russian and Chinese involvement on the Korean Peninsula

It is generally thought to be unlikely that either Russia or China would become embroiled in a nuclear exchange on the Korean Peninsula by detonating their own nuclear weapons. For several reasons, these states are more likely to support the DPRK by bolstering its conventional capabilities than by detonating their own nuclear weapons. (1) They may be interested in preserving the DPRK as a state because it provides a buffer zone between US allies and their own territory; (2) the DPRK no longer needs a nuclear umbrella like the ROK, given that the DPRK now has its own nuclear weapons arsenal, and (3) it is in their interest to keep the United States embroiled in a conflict on the Korean Peninsula, thereby diverting its attention from conflicts or potential conflicts elsewhere in which Russia and/or China have interests. An unprecedented nuclear use on the Korean Peninsula might quickly lead to a dissolution of the DPRK or the end of the Korean conflict, and subsequent withdrawal of US troops from the ROK, freeing the United States to turn its attention to tensions in Eastern Europe or the South China Sea.

Conclusion

Low-yield nonstrategic nuclear weapons were developed and deployed during the Cold War for the purpose of providing a “tactical” deterrent against the advance of conventional troops, but in theory, low-yield weapons can be used to achieve a variety of effects. It was originally thought that the use of low-yield nuclear weapons might be necessary to offset overwhelming enemy conventional forces.

As conventional weapon systems evolve to become more sophisticated, the use of low-yield tactical nuclear weapons becomes less attractive for nations with highly advanced military technologies. Modern weaponry such as precision-guided munitions, drones, and advanced surveillance technology can now be used to achieve many of the same effects for which Cold War military planners sought to use low-yield nuclear weapons. A low-yield nuclear option may, however, still be attractive for nations looking to compensate for perceived conventional military inferiority. Therefore, a hypothetical nuclear exchange in the shadow of evolving contemporary technologies must consider many new factors that were not necessary to contemplate in traditional nuclear deterrence and detonation theory.

Plausible nuclear use cases on the Korean Peninsula should be based on an understanding of contemporary technological evolutions and their political effects and how these may intertwine with or precipitate a low-yield nuclear use. This will require an understanding of nuclear and conventional deterrence theory outside of the traditional Cold War-era line of thought. Low-yield weapons as both strategic and nonstrategic weapons could be considered in light of conventional technology advancements.

Future research priorities to aid in responding to these issues include conducting interviews with more national security and technical experts in the nations party to the Korean conflict. A deeper dive into the technicalities of modern conventional weaponry and low-yield nuclear warheads and their delivery systems could aid in understanding how conventional technological evolutions

affect the plausibility of nuclear weapons use. It may also help to acquire a better understanding through simulations of how the height of burst of a low-yield nuclear weapon affects infrastructure damage, nuclear fallout, the electromagnetic pulse from detonation, and other nuclear weapon effects. Finally, understanding prevailing wind patterns on the Korean Peninsula corresponding with various heights of burst will be of interest when examining nuclear fallout effects.

Appendix A: Technical Definition of a Kiloton

Since the days of the Manhattan Project, when the use of US Customary Units was still common in science and engineering in the United States, the definition of the nuclear “kiloton” has remained slightly ambiguous. Here follows a summary of the various definitions used and some potential consequences of this ambiguity.

The original authoritative source on nuclear weapons, *The Effects of Nuclear Weapons*, 3rd edition by Glasstone and Dolan, published by the United States (US) Department of Defense and US Department of Energy in 1977, defines “kiloton energy” as “ 10^{12} calories. This is approximately the amount of energy that would be released by the explosion of 1 kiloton (1,000 tons) of TNT.” Furthermore, “the basis of the TNT equivalence is that the explosion of 1 ton of TNT is assumed to release 10^9 calories of energy.”³⁵

Table 1.45 from that source (reproduced below) summarizes various equivalents to one kiloton of TNT. According to Glasstone and Dolan, “the calculations are based on an accepted, although somewhat arbitrary, figure of 10^{12} calories as the energy released in the explosion of this amount of TNT.”³⁶

Table 1.45: Equivalents of 1 Kiloton of TNT

- Complete fission of 0.057 kg (57 grams or 2 ounces) fissionable material
- Fission of 1.45×10^{23} nuclei
- 10^{12} calories
- 2.6×10^{25} million electron volts (MeV)
- 4.18×10^{19} ergs (4.18×10^{12} joules)
- 1.16×10^6 kilowatt-hours
- 3.97×10^9 British thermal units

Glasstone and Dolan explain the origin of some ambiguity surrounding these definitions:

The majority of the experimental and theoretical values of the explosive energy released by TNT range from 900 to 1,100 calories per gram. At one time, there was some uncertainty as to whether the term “kiloton” of TNT referred to a short kiloton (2×10^6 pounds), a metric kiloton (2.205×10^6 pounds), or a long kiloton (2.24×10^6 pounds). In order to avoid ambiguity, it was agreed that the term “kiloton” would refer to the release of 10^{12} calories of explosive energy. This is equivalent to 1 short kiloton of TNT if the

³⁵Glasstone, Samuel, and Philip J. Dolan. 1977. *The Effects of Nuclear Weapons*. 3rd ed. N.p: United States Department of Defense and Department of Energy. https://www.dtra.mil/Portals/61/Documents/NTPR/4-Rad_Exp_Rpts/36_The_Effects_of_Nuclear_Weapons.pdf

³⁶Ibid., p. 13.

energy release is 1,102 calories per gram or to 1 long kiloton if the energy is 984 calories per gram of TNT. (Glasstone & Dolan, 1977, p. 13)

Despite the formal definition equating one kiloton to a tera-calorie, Lawrence Livermore and Los Alamos National Laboratories have debated the kiloton definition³⁷ based on the immediate versus delayed fission yield of nuclear weapons. The total energy released is equivalent to about 240 MeV per fission. However, a fraction of this fission energy is carried away in neutrinos and delayed radioactive decay (fallout). Therefore, some consider the true definition of a kiloton to be equivalent to the immediate explosive yield of 180 MeV per fission.

³⁷Pincus, Walter. "2 Labs Battle To Be No. 1." *The Washington Post*, December 12, 1978.
<https://www.washingtonpost.com/archive/politics/1978/12/12/2-labs-battle-to-be-no-1/20a1a894-4867-4f9d-97d0-183c6c6d844e/>

Appendix B: HYSPLIT Simulation Parameters

Parameter	Surface-burst	Airburst
Meteorology data (Wind speed/direction, precipitation)	GFS 0.25-degree ³⁸	"
Yield	0.3 kt & 10 kt	"
Date / Time	2021 08 01 00 00 UTC	"
Ground Zero Coordinates	37.915, 126.698	"
Height of Burst (HOB)	0 m	147, 474 m ³⁹
Cloud Layers ⁴⁰	0 m 0 m 631 m 2560 m 947 m 3840 m 1353 m 5486 m	Each cloud layer is raised by the HOB. (Ex. 1353 m +147 m)
Release Duration ⁴¹	6 minutes	"
Activity Distribution ⁴² (cap / skirt / stem)	0.775 / 0.15 / 0.075	0.9712 / 0.0283 / 0.0005
Particle Size Distribution ⁴³	$X \sim \text{Log}N$ ($d = 0.407\mu\text{m}, \sigma = 4$)	$X \sim \text{Log}N$ ($d = 0.150\mu\text{m}, \sigma = 2$)
Moment of Distribution	2.5	3
# Particle Size bins	100	"
Particle Density	2.5 g/cc	4.8 g/cc
Total Run Time	96 hours	"
Output Grid	Spacing: 0.05° Span: 20° Layer Heights: 0, 300 m	"

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³⁸Meteorology data provided by the NOAA Air Resources Laboratory through the READY website at <https://www.ready.noaa.gov/index.php>

³⁹"Optimum" HOB for airbursts estimated based on comparison to Hiroshima/Nagasaki HOBs, which were selected to maximize the area affected by an overpressure of 10-15 psi. Equation in Glasstone and Dolan, *The Eff. Of Nuc.*, p. 110.

⁴⁰Ibid., p. 34. Top of stabilized cloud height.

⁴¹Ibid., p. 32. Length of time it takes for the mushroom cloud to stabilize.

⁴²Philippe, Sébastien, Sonya Schoenberger, and Nabil Ahmed. "Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia." Moruroa Files. Last modified March 9, 2021. Cornell University (arXiv:2103.06128v1). Activity Distribution and other parameters selected from this previous study.

⁴³Norment, H G. "DELFI: Department of Defense fallout prediction system. Volume I – fundamentals. Final report 16 Jan-31 Dec 79." United States.